ADVANCED PRODUCTION & QUALITY MANAGEMENT

LESSON PLAN

Course Number: PQM 301

Module & Title: Lesson No. 3 A, B, C, Analytical Tools Case
A – Intro to Analytical Tools
B – Research Time
C – Student Presentations

Length (total): 8 Hours

Terminal Learning Objective:

Given the lecture/discussions a student will demonstrate an understanding of several functional tools associated with manufacturing and quality assurance.

Through student presentations students should be able to select the appropriate analytical tool to resolve production and quality assurance problems and analyze the interrelationships of these tools.

Enabling Learning Objectives:

1. **Identify several analytical tools for use during the design phase.**

2. **Identify several analytical tools for use during the production phase.**

3. **Select the appropriate analytical tools to solve specific design and/or production problems.**

4. **Analyze the interrelationships of these tools.**

Learning Method: Lecture/Discussion/Research/Presentations

Student Readings: Teaching Note: "Manufacturing Questions Program Managers Should Ask"

Background References: None

Conduct of the Lesson:

Lesson 3A is an introduction to several of the analytical tools, which will be discussed during APQMC. During this lesson, the instructor will outline the requirements and timeline for student research and presentations expanding on their experiences with these tools. This portion of the lesson is primarily lecture and discussion.

Prior to the start of Lesson 3B, each student should have selected and received instructor approval of the topic for their research and presentation. Students should select a tool they have used recently in their Manufacturing/Quality jobs to identify and/or manage risk associated with a specific design and/or production problem. Students not in the Manufacturing/Quality career field should discuss alternate topic selections with their instructor. In their presentations, students will:

- Describe the design and/or manufacturing problem
- Explain how the problem was discovered
- Discuss use of the chosen analytical tools to identify or solve the problem

Lesson 3B consists of two hours of in-class research and preparation time. The classroom, an automated classroom, the Learning Resource Center and Acker Library are available for research and presentation preparation.

During the first hour of Lesson 3C, each student will brief the results of his/her research to their perspective workgroups. Each workgroup will then discuss the diversity of the presentations and select and prioritize two primary and two alternative presentations for presentation to the entire class. The selected briefings will then be presented to the entire class as time allows. (Historically, all primary and about half the alternate briefings are presented to the entire class.)

MANUFACTURING QUESTIONS PROGRAM MANAGERS SHOULD ASK

Lt Col Robert Hartzell

and

Lt Col Dave Schmitz

This article discusses several tools available to bring manufacturing considerations into the design process earlier and reduce risk through the application of a quality system.

WHAT IS MANUFACTURING

The term “manufacturing” covers a broad set of functional tasks required to harness all the elements needed to make a product. Included are such wide-ranging topics as analysis of the National Technology and Industrial Base (NTIB) capabilities to support the program, methods to influence the design for cost effective manufacturing, identification of the people and skills needed for design and production, and selection of material, appropriate methods of production, capable machinery, scheduling, measurements, and quality assurance management systems. Manufacturing requires the support of functional specialties from a diverse set of organizations, to include matrix assigned manufacturing managers, other program office functionals, contract administration services people, laboratories, contractors, and commodity staffs as well as depot personnel.

Historically, 30 percent of a program’s total costs are consumed by production activities. Moreover, this significant investment is spent within a relatively short amount of time. Additionally, transitioning a system from development to production has also historically proven difficult, with attendant cost penalties. A Defense Science Board study revealed that 30% of our production costs are non-value added. (This is often called the cost of quality or the “Hidden Factory”).

WHAT’S NEW

Today’s acquisition environment offers new opportunities to reduce program risks, but also poses new challenges to program managers. From a manufacturing perspective, there are three important trends: DoD downsizing, acquisition reform, and technology improvements. Reduced requirements equate to fewer production programs and severe reductions in programs that do go forward. The effect is a potential loss in critical skills required of design teams in terms of designing for production, and less experience for production planning, scheduling and controlling. Additionally, longer service lives and purchasing commercial off-the-shelf and non-developmental items (NDI) as a policy initiative will mean more ACAT III programs with unique risks accompanied by the challenges of reduced functional support and smaller staffs.

Acquisition reform also brings new opportunities and challenges to the PM world. Simplified contracting actions, increased reliance on commercial specifications and standards and less functional support bring significant opportunities to better integrate the National Technology and Industrial Base and make more of it available to meet DoD requirements. This adds other unique challenges: What is a "Best Commercial Practice"? How good is it? Will the contractor's system meet my risk management needs?

Advances in information technology have enabled manufacturing management techniques to be implemented in an affordable and effective manner. Some of the tools described below (e.g. design of experiments) and producibility engineering and planning are easier to do with today's computers and software. Their wide spread use can significantly reduce program risks.

DSMC MANUFACTURING MANAGEMENT CURRICULUM

We believe 80 percent of a manufacturing functional's job is influencing the design and getting ready for production; toward that end, our curriculum is designed to convey current DoD policies, regulations, and management tools related to manufacturing in defense acquisition. This philosophy is valuable in the two week Advanced Production and Quality Management Course. In this course, students will receive updates on the latest policies and initiatives impacting the manufacturing function. Additionally, students will be exposed to Best Practices being employed by world class producers in both the defense and commercial facilities of the NTIB.

ANALYTICAL TOOLS FOR RISK REDUCTION

Development Tools:

IPPD/IPTs

As mentioned above, we put a great deal of emphasis on the importance of influencing the design process for manufacturability. One way to do that is to implement Integrated Process and Product Development (IPPD), using Integrated Product Teams, or IPTs.(1) IPPD attempts to optimize the design, manufacturing, and supportability processes through the use of teams populated with appropriate functional area representatives who can concurrently perform required acquisition activities. IPTs are composed of representatives from all appropriate functional disciplines working together with a Team Leader to build successful and balanced programs, identify and resolve issues, and make sound and timely decisions. The purpose of IPTs is to make team decisions based on timely input from the entire team (e.g. program management, engineering, manufacturing, test, logistics, financial management, procurement, and contract administration) including customers and suppliers.

IPPD is working in the commercial market place, as well as in the defense industry. At Chrysler IPTs are called platform teams, and were used to develop the LH (mid-sized sedans) platform. Chrysler needed only 39 months versus the 54 months they had needed in the past to develop and launch the cars. The company used 740 engineers to work on the LH cars, compared to the 2000 used on earlier platforms. The factory where the LH cars were made needed just 3000 employees for full two-shift production, whereas earlier platforms had needed as many as 5,300. (2)

The first logical question to ask is *"What engineering design tools used during development, integrate manufacturing processes and affordabililty into the design?"* Here are some of the tools available:

Quality Functional Deployment (QFD)

Quality Function Deployment (QFD). Programs in development face many risk drivers to cost, performance and schedule. One of those drivers is customer requirements, especially when those requirements keep changing, are soft, or are not fully or adequately developed. A core development task is the gathering of requirements and the translation of these requirements into technical solutions.(3) QFD is a planning process which uses multi-functional teams to get the voice of the customer into the design specifications. User requirements and preferences are defined and categorized as user attributes, which are then weighted based on importance to the user. Users are then asked to compare how their requirements are being met now by a fielded weapon system (or an alternative design approach) versus the new design. QFD provides the design team an understanding of customer desires (in clear text language), forces the customer to prioritize those desires, and compares/benchmarks one design approach against another. Each customer attribute is then satisfied by at least one technical solution. Values for those technical solutions are determined, and again rated among competing designs. Finally, the technical solutions are evaluated against each other to identify conflicts. A convenient form for viewing the ultimate product is the "house of quality" (Figure 1), which should help the design team translate customer attribute information into firm operating or engineering goals, and identify key manufacturing characteristics.

Figure 1. House of Quality

ANALYTICAL TOOLS

- Quality Function Deployment
  - A planning process using IPPD
  - Understand ‘voice of customer’
  - Translate ‘voice’ into high level system requirements and product specifications
  - Prioritize requirements

The QFD “house of quality” can be viewed as having two main parts. The first is the customer part, which is designed to allow customers to express needs in terms they understand. These needs usually are translated into a language the developer can use internally to describe and measure the item. For example, a customer requirement for a car door may be that it “closes easily.” The developer might translate that requirement into force measured in pounds. The second part of the “house” is the technical information section in which at least one technical solution is described for each customer need. A possible technical solution in this case may involve the type of latching mechanism selected.

Design for “X”

Design for “X” refers to a series of design approaches to achieve specific design-build objectives. DFX includes Design for Manufacture and Assembly (DFMA), Design for Recycling (DFR), Design for Fabrication, etc. DFMA focuses specifically on defining product design options for ease of fabrication and assembly. The goal is to integrate the manufacturing engineer’s knowledge of the factory floor (i.e. manufacturing processes), along with the use of design principles and rules, to develop a more producible product. Examples of the design rules include minimizing part count, using standard components, designing parts for ease of fabrication, and avoiding separate fasteners. DFMA can also

provide secondary benefits by increasing reliability, reducing inventory, and shortening product development cycle time. Design for Recycling focuses specifically on achieving an optimization of recycling and reuse of materials at the end of a product's life cycle.
Design of Experiments (DOE)

<u>Design of Experiments (DOE).</u> There are many factors that affect the quality of the end item. If our goal is to design and build quality into our products, we must control those factors that have the greatest impact on fit, performance, and service life. Most experimentation done today on the factory floor is done by accident. That is, manufacturing personnel first turn one knob (speed) up, and another knob (temperature) down in an attempt to bring product quality in line with specification requirements. They often change several factors at the same time and fail to collect, or analyze data. They are not understanding the process, they are just tampering with the system. DOE provides a structured way to characterize processes. A multi-functional team analyzes a process and identifies key characteristics, or factors that most impact the quality of the end item. Using DOE, the team runs a limited number of tests and data is collected and analyzed. The results will indicate which factors contribute the most to end quality, and will also define the parameter settings for those factors. Now, rather than tweaking or tampering with the system, production managers have the profound knowledge of their factory floor processes which allow them to build quality in, starting at the earliest stages of design.

How will management determine that equitable requirements tradeoffs are made between design and manufacturing processes during development?

The answer to this question will vary based on the phase of the acquisition program. At Preliminary Design Review for instance, our contractor should provide evidence of performing producibility analyses on development hardware trading-off design requirements against manufacturing risk, cost, production volume and existing capability/availability. Production planning demos should address material and component selection, preliminary production sequencing methods and flows concepts, new processes, manufacturing risk, facility/equipment usage for intended rates and quantities, and acceptance test and inspection concepts.

Cost as an independent variable requires increased focus on cost as an input to the design process. Design-to-cost goals should be established with the help of the manufacturing IPT. For example, an air superiority fighter program has a design-to-cost goal based on previous fighter programs, where 32% of life cycle costs are consumed in production. The manufacturing IPT's goal would be to reduce that number by some portion (e.g. 4%) while not penalizing O&S or R&D costs.

Of those manufacturing processes that do not exist or are unproved, what is planned to prove them out?

The primary way of doing this, is by comparing program needs to work being done under the DOD's Manufacturing Science and Technology (ManTech) Program. The objective of this program is to develop or improve manufacturing processes, techniques, materials, and equipment to provide timely, reliable and economical production of defense systems. Another way is to monitor service laboratories' technology investment plans and technology area planning. In either case, the goal is to ensure advanced manufacturing technologies are being considered by the contractor, the government, preferably both. We want to conduct process proofing as demonstrated in a factory representative environment before rate production begins.

Quality Systems

As noted above, DOD has relied in the past on specifications and standards to promote competition and to ensure high quality products or processes. Specifications and standards were easy to use and put on contract, and also eased the source selection process because buyers (especially for numerous low cost, commercially available items) could focus on cost versus quality. With today's emphasis on performance specifications and commercial standards, the program manager's best way to influence product quality is through implementation of a quality system.

How does the contractor plan to implement process control?

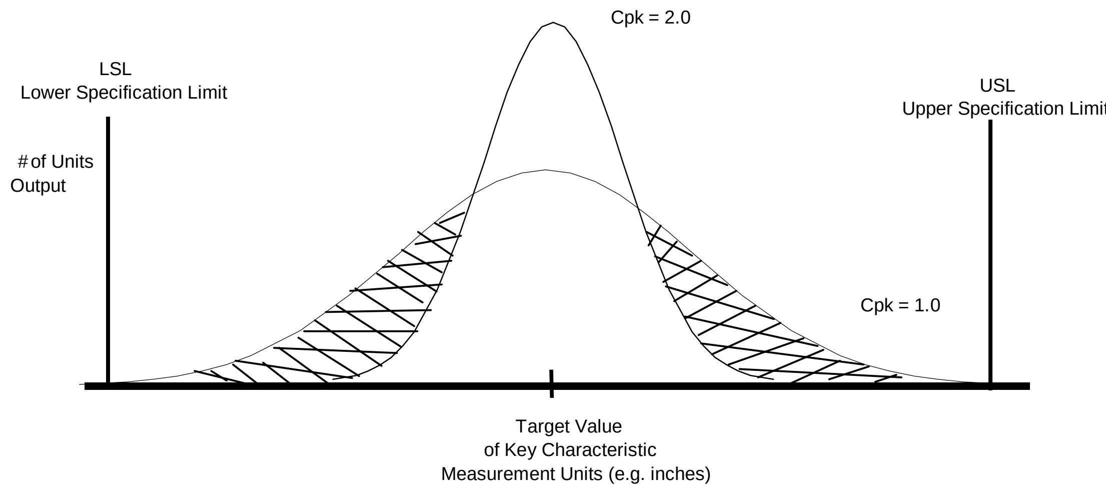
Implementation of a quality system is the best way to control processes. Elements of a basic quality system (e.g. ISO 9000) which contribute to process control include corrective and preventive actions, training, calibration of measurement and test equipment, nonconforming product control, control of purchased materials and components, use of statistical techniques, and use of internal audits.

I want to go beyond ISO 9000 to manage the risk on my program. What advanced quality concepts should I pursue?

Many of the tools and techniques already addressed would contribute to advanced quality. Another is the concept of Key Product Characteristics (KPCs). The identification of KPCs, their design limits, and the identification of key production processes and their capabilities are engineering tasks which support manufacturing development. The intent is to: identify those characteristics of the design which most influence performance, supportability, and cost (see the QFD discussion above); determine the production processes which effectively and affordably meets the product requirements; verify the capability of the processes; and develop the required process control for production.

Product variation is the silent killer on the factory floor. As KPCs vary from nominal, losses occur usually in the form of scrap, rework, or repair; if products are fielded, then losses include degraded performance, lower reliability and increased support costs, or upset customers. Once KPCs are identified, associated key processes can be evaluated for affordable maximization of process capability (Cpk), Figure 2. This implies further that a Process Control Plan be developed which ensures that required product quality is achieved at the lowest possible cost. Process Control Plans include the use of process control charts, statistical process control to differentiate common from special causes of variation, and gage variation studies to minimize errors in measurement.

Figure 2. Reducing Variation



Variation is the silent killer on the factory floor, because it can significantly impact product quality. Process capability (Cpk) is a unitless measure of product quality based on the normal distribution of product output around the nominal or target value. (Note: Process capability calculations can be made for other than normal distributions.) Both processes are within specification limits. But minimizing variation, especially for key characteristics is usually beneficial. Problems that occur with products falling in the cross-hatched areas include degrades performance, increased support costs, and higher product rework rates.

How will development hardware be used to demonstrate fabrication, assembly, test and production processes?

Development hardware, while usually used to gauge initial compliance with specifications, should also be used to demonstrate manufacturing processes. At this stage in the acquisition life cycle (typically Product Definition and Risk Reduction or early EMD), manufacturing processes can be characterized as:

- Existing and capable— Indicates little work is needed since quality requirements can be met by current manufacturing techniques.

- Existing but not capable— Indicates the manufacturing process may be known, but not fully capable of meeting program rate, quality, or performance goals. This presents risk to the program; a plan needs to be developed to mature this technology, find a suitable alternative, or perhaps both.

- Nonexistent— Development hardware was produced using techniques not transferable to the factory floor. This presents significant risk to the program; a plan needs to be developed to develop this technology, find a suitable alternative, or perhaps both.

How can continuous process improvement be incentivized?

One way is to use award fees based on reductions in the variance of KPCs, i.e. increase Cpks, without increasing costs of the end item/component. Another method is to use award fees or savings sharing plan based on reduction in process costs that do not sacrifice performance or schedule.

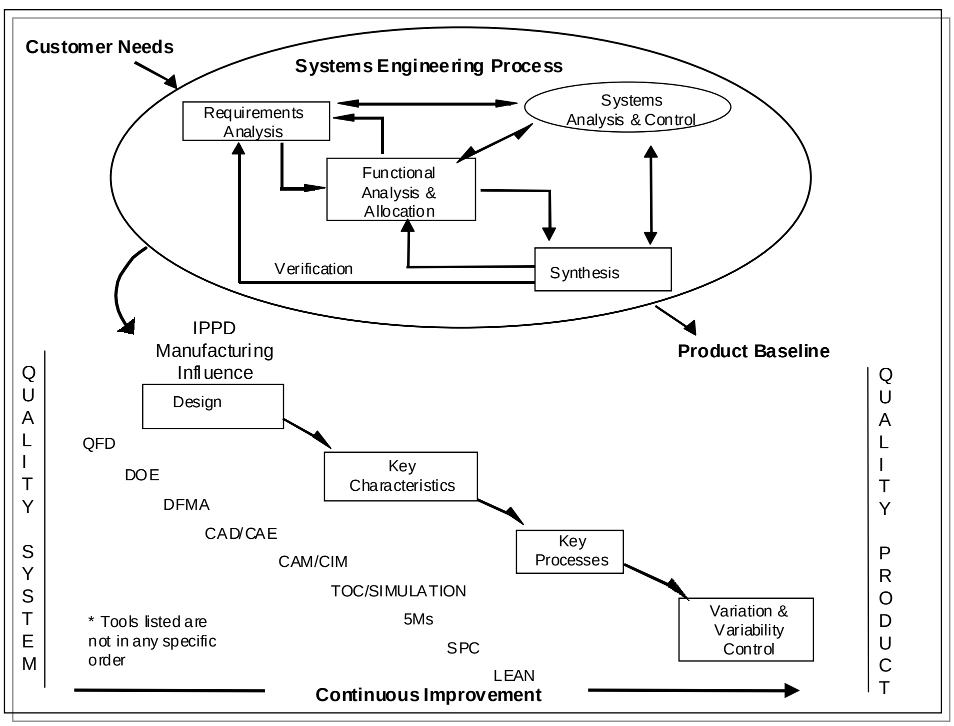
In this reading we have looked at systemic changes in the acquisition environment which may impact defense manufacturing in particular. We started at the earliest stages of design, and described some of the tools available to the manufacturing functional to make that design more producible. In the quality section we covered some advanced quality tools, and saw again that a quality product in the end starts with the design.

Endnotes

1. Secretary of Defense letter, "Use of Integrated Product and Process Development and Integrated Product Teams in DoD Acquisition," 10 May 95.
2. Ingrassia, Paul and White, Joseph B., "Shifting Gears," *America West Airlines Magazine*, November 1994, p.52.
3. Lang, James D. and Hugge, Paul B., "Lean Manufacturing for Lean Times," *Aerospace America*, May 1995, p.28.

INTRODUCTION TO ANALYTICAL TOOLS

Introduces Analytical Tools that will be taught during subsequent lessons



ANALYTICAL TOOLS

- The 5 Ms
  - Manpower
  - Machines
  - Materials
  - Methods
  - Measurement

ANALYTICAL TOOLS

- Statistical Process Control
  - A way of understanding variation from nominal of key product characteristics
  - Allows management decisions to be made based on profound knowledge of process identity and predictability of output

ANALYTICAL TOOLS

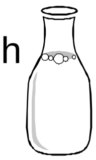
- Design of Experiments
  - Structured, economical experimentation
  - Used to develop robust designs
  - Used to develop robust processes through
    - identification of process parameters and
    - settings that lead to superior product characteristics

ANALYTICAL TOOLS

- Quality Function Deployment
  - A planning process using IPPD
  - Understand ‘voice of customer’
  - Translate ‘voice’ into high level system requirements and product specifications
  - Prioritize requirements

ANALYTICAL TOOLS

- Theory of Constraints
  - Controls production resources through identification of bottlenecks
    - Bottlenecks are resources whose capacities are less than the demand placed on them
  - Goals are to increase throughput, decrease inventory and decrease operating expense



ANALYTICAL TOOLS

- Lean Manufacturing
  - The language of “lean”
    - Value Stream
    - Get the WASTE out
  - The Lean Aerospace Initiative
    - The Lean Enterprise Model

ANALYTICAL TOOLS

- Presentation Guidelines
  - 5 Minute presentation/5 minute Q&A
  - Good information/not fancy
  - Instructor topic approval S: Tuesday Wk 2
  - In-class research time
  - Turn in hard copy or e-copy

ANALYTICAL TOOLS

- Potential Topics
  - Analytical Tools
  - Other PQM-related tools and subjects
    - Risk Management
    - Acquisition Reform
    - Producible Design (DFMA); CAD/CAM/CID
  - Potential Approach:
    - Lesson learned
    - Real world examples
    - Library research

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